DOCUMENT RESUME

ED 374 770 IR 016 808

AUTHOR Lai, Yee-Rong; Waugh, Michael L.
TITLE From Information Searching to Learning: A Comparison of Contrasting Hypertextual Menu Designs for Computer-Based Instructional Documents.
PUB DATE Apr 94
NOTE 25p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 4-8, 1994).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150) -- Tests/Evaluation Instruments (160)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; Higher Education; *Hypermedia; *Information Seeking; *Instructional Design; *Menu Driven Software; Problem Solving; Questionnaires; *Search Strategies
IDENTIFIERS *Document Structure

ABSTRACT

This study examined the influence of three different combinations of document structures and menu designs on users' attitude, performance, and learning in five different search tasks. The three types of combinations studied were: (1) an explicit menu signaling hierarchical structure where cross-referencing was not supported (EXH--explicit and hierarchical); (2) an explicit menu signaling hierarchical structure in which cross-referencing capability was embedded (EXN--explicit and network); and (3) an embedded menu signaling both hierarchical structure and cross-referencing capability (EMN--embedded and network). Based upon the specificity, complexity, and boundary of the search targets, five types of searches were studied--when the target was: simple and fully known; simple but not partially known; complex and fully known; complex but only partially known; and complex and the condition for terminating the search was unclear. Results showed that providing cross-reference links in small- or medium-sized online documents can improve search accuracy but not efficiency. EXN produces the best search accuracy, and EMN encourages in-depth search for tasks that are complex and not fully known. Although EXN was best received by the subjects, it resulted in a greater sense of getting lost for those who used the referential links and backtracking links more often. Causes of this disorientation, reasons why EXN and EMN produced better performance were discussed and search strategies employed by the subjects were investigated. The questionnaire used in the study is appended. (Contains 54 references.) (JLB)

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From Information Searching to Learning: A Comparison of Contrasting Hypertextual Menu Designs For Computer-Based Instructional Documents

Yee-Rong Lai
Michael L. Waugh

University of Illinois

Paper presented at
AERA Annual Meeting, New Orleans

April, 1994

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Abstract

This study examined the influence of three different combinations of document structures and menu designs on users' attitude, performance, and learning in five different search tasks. The three types of combinations studied were: (a) an explicit menu signaling hierarchical structure where cross-referencing was not supported (EXH--explicit and hierarchical), (b) an explicit menu signaling hierarchical structure in which cross-referencing capability was embedded (EXN--explicit and network), and (c) an embedded menu signaling both hierarchical structure and cross-referencing capability (EMN--embedded and network). Based upon the specificity, complexity and boundary of the search targets, the five types of searches studied were when the target was: (a) simple and fully known, (b) simple but only partially known, (c) complex and fully known, (d) complex but only partially known, and (e) complex and the condition for terminating the search was unclear. The results of the study showed that providing cross-reference links in small or medium-sized online documents can improve search accuracy, but not efficiency. EXN can produce the best search accuracy in most cases and EMN will encourage in-depth search for tasks that are complex and not fully known. Although EXN was best received by the subjects, it resulted in a greater sense of getting lost for those who used the referential links and backtracking links more often. The causes of this sense of disorientation and the reasons why EXN and EMN produced better performance were discussed, and the search strategies employed by the subjects were investigated.

INTRODUCTION

The hypertext concept has been embraced and studied by many instructional designers, educational psychologists, technical communicators, and cognitive, computer, and information scientists. Educational researchers believe that hypertext is an ideal knowledge representation format that makes generative or adaptive learning possible (Dede, 1987, 1988; Jonassen, 1986, 1988) and that hypertext is suitable for exploratory learning for ill-structured, advanced knowledge domains or literary education (Landow, 1989; Spiro & Jehng, 1990; Spiro, Feltovich, Jacobson, & Coulson, 1991). Some see hypertext as a platform for multidisciplinary learning in the increasingly complex and growing field of science (Davenport & Cronin, 1990; Marchionini & Shneiderman, 1988). Some see hypertext and its extension--hypermedia--as a new CBI (computer-based instruction) authoring environment (Park, 1991), and some see a new type of CBI application emerging--hypermedia-assisted instruction, or HAI (Heller, 1990).

However, with all the fervent discussions and studies, it is still very difficult to articulate empirically determined guidelines for implementing online instructional documents. There are three reasons: First, the text types and reading purposes vary in these studies and sometimes are not clearly classified (Dillon, 1990). While many studies focus on information searching, detailed information regarding the complexity and specificity of the search tasks are seldom provided. Second, the menu designs of the systems studied are often different and vaguely described. Some use what Ben Shneiderman calls "embedded menu," i.e., users select a word or phrase of interest from within a paragraph to see more detailed information regarding that word or phrase. Some use the traditional menu structure where organizational components are explicitly separated from the content, and selection in context is only used for referential or associative links, not organizational relationships. Third, the definition of hypertext as non-linear text can be vague too. Can hierarchically organized information bases be classified as hypertext? A strictly hierarchically organized text without the support for associative or referential links is far from the ideal of hypertext--a network of ideas/concepts connected based on their associative relationships. We often cannot tell if some studies provide associative or referential links in addition to organizational links to qualify them as hypertext systems. As a corollary to the above problems, it is difficult to conclude from previous studies comparing linear and non-linear systems whether hypertext systems are suitable for information searching. Studies comparing different hypertext browsing systems also cannot explain what it is that contributes to the difference in user performance as too many potentially significant variables are different across these systems (Rada, 1991).

Information Searching

People often learn through searching for information when they encounter problems. Jonassen and Grabinger (1990) rightly claim that information seeking is "a fundamental learning activity, precursive to many others" (p. 7). It is also a "pervasive human activity" (Nickerson, 1986) and "a special case of problem-solving" (Marchionini, 1989). With computers' capability of massive storage, easy manipulation, and fast retrieval of information, more and more documents are put online, and electronic databases have demonstrated their potential as a learning resource. Interaction with electronic databases bas become "a matter of the utmost concern for education and training" (Cotterell, Ennals, & Briggs, 1988).

As problems can be classified into two broad categories, i.e., well-defined and ill-defined, in terms of the clarity of the starting point and goal, search targets are different in their complexity and specificity. However, in most studies, information searching is often defined as looking for answers to specific and explicit questions. A study of users' navigation in a database environment found that database users use databases for purposes more than just factual retrieval, and there are five discernibly different searching strategies: scanning, browsing, searching, exploring, and wandering (Canter, Rivers, & Storrs, 1985). These five searching strategies are defined as:

Scanning: covering a large area without depth.
Browsing: following a path until a goal is achieved.
Searching: striving to find an explicit goal.
Exploring: finding out the extent of the information given.
Wandering: purposeless and unstructured globetrotting.

This account of search strategies provides a more complete picture that encompasses the wide range of information searching activities in which users may be involved under real learning and information searching situations. Research has shown that information searchers prefer using search facilities such as keyword search or index (Joseph, Steinberg, & Jones, 1989). But when search questions are vague, people tend to resort to the browsing or exploring strategies (Marchionini & Shneiderman, 1988). Tonta (1991) has argued that "hyptertext systems are not designed for fast and efficient fact retrieval. Rather they support unhurried and informal information searching" (p. 22). Therefore, when the search task is simple and specific, comparison among different browsing systems is actually a comparison of search facilities provided in each system rather than a comparison of the structure or interface design. The difference a network-structured system can make cannot be found if the search facilities provided are different in the systems compared or if search tasks studied are limited to simple and specific facts.

Wright (1990) argues that a decomposition of search tasks is necessary in order to understand the implications of functionalities of and interface designs for hypertext systems. Based on how many elements are needed in order to answer a question (i.e., complexity), whether each element is known (i.e., specificity), whether each element is specifiable to the computer (i.e., specifiability), and whether there is a clear terminating condition for the search task (i.e., boundary), Wright (1990) proposes six different types of search tasks:

1. Search target simple and fully known;
2. Search target simple but only partially known;
3. Search target complex and fully known;
4. Search target computed from online trade-offs and feedback from the computer;
5. Search target simple but unspecifiable to a computer; and
6. Search target unrecognizable for the purposes of terminating the search. (pp. 176-178)

Another taxonomy of five criteria was used to classify search questions in an attempt to assess incidental learning during information retrieval (Jones, 1989). The five criteria are based on how many concepts/components are presented in the question (complexity), how easy it is to determine the major entry point for information access (specificity), how easy it is to determine the appropriate label as used in the document (focus), how many articles need to be selected in order to find the answer (path), and how easy it is to find the right path to the answer (accessibility). Marchionini (1989) reported that users tend to simply follow the links and use low cognitive load strategies when browsing a hypertext system. Will a hypertext system with associative links distract information searchers from their search goal (Foss, 1989) and encourage serendipitous findings? Or will it expedite the search? Will it result in what Foss (1989) calls the "art museum phenomenon," i.e., learners browse through many different parts of the document but have difficulties in forming a coherent understanding or abstraction of what has been seen? Or will it help make an unclear search goal clearer? How would this influence a user's sense of control, confidence in understanding the material and confidence in using such systems?

Document Structure

Hierarchical structure is the most common structure used in online documentation, as well as in many computer-based instructional programs. "Hierarchical structures are the most natural structures for organizing levels of abstraction" (Conklin, 1987, p. 35). As a matter of fact, online writing started out by imitating conventional writing on paper, the goal of which is to create "a perfect hierarchy" (Bolter, 1991). According to Ausubel (1968), our semantic networks are arranged hierarchically, and research also shows that people construct hierarchical representation of the text they read (van Dijk & Kintsch, 1983). Hierarchy is not only a natural organization for texts but also a natural strategy for information searching. The organizational structure of a database is found to be

the primary determinant of information-searching performance, as it structures the knowledge as well as defines how the knowledge can be accessed (Marchionini & Shneiderman, 1988). Guthrie, Britten, and Barker (1991) propose a five-component cognitive model for information searching: (a) goal formation, (b) category selection, (c) extraction, (d) integration, and (e) recycling. In a series of studies, category selection was found to be the most crucial and time-consuming one among the five (Guthrie, 1988; Guthrie & Dreher, 1990). This model is also found to be adequate for both sharp and fuzzy problems, i.e., problems that are clear and specific and problems that are vague (Guthrie & Dreher, 1990). Based on this model, a hierarchical structured document should help facilitate information searching as it reduces time spent on category selection by trimming unlikely branches.

However, with computers and the concept of hypertext, hierarchical and associative thinking can coexist, allowing learning of and searching through both organizational and associative relationships. It is generally agreed that hypertext systems should provide a proper organizational structure to enhance comprehension and information retrieval (Herrstrom & Massey, 1989; Jaynes, 1989; Jonassen, 1988; Jonassen & Grabinger, 1990; McKnight, Dillon, & Richardson, 1991; Rubens, 1989; Simpson & McKnight, 1990), help form an accurate mental model of the systems (Holt, Boehm-Davis, & Schultz, 1986), and provide an "ideational scaffolding" (Ausubel, 1974) so that "a user's expectations can be confined and become more educative." (McAleese, 1989, p. 15). Some believe that by accelerating access without enhancing structural cues, it will be more difficult for users to make sense of where they are in the documents (Carey, Hunt, & Lopez-Suarez, 1990). In the paper world, a table of contents is usually given at the beginning to provide a systematic list of headings identifying the items discussed in the document; it is "an aid to both way-finding and sense-making" (Carey, Hunt, & Lopez-Suarez, 1990, p. 582). The power of hypertextual structure that builds on hierarchy is that it allows hierarchical and associative thinking to coexist. While tree-structured databases are often classified as non-linear, many systems often lack the kind of links that make a system a hypertext system: the referential links. Therefore, research is needed to find out whether and how users interact differently in strictly hierarchically-structured systems and in hypertext systems that provide referential links in addition to hierarchical organization.

Explicit Menus Vs. Embedded Menus

In computer-based instruction, menus are "lesson-structuring devices... [The] design of a menu system imposes an implicit or tacit structure on the lesson which influences the learner's 'usage patterns'" (Schuerman & Peck, 1991, p. 93). One common type of menu is an enumerated list of possible choices, which explicitly signals the organizational structure. An alternative to such explicit menus are embedded menus: embedding the menu choices within the texts. Two possible drawbacks of explicit menus are verbosity and ambiguity, which are the results of extracting segments from the original context to form a list of menu items (Koved & Shneiderman, 1986). With embedded menus, on the contrary, it is easier to avoid ambiguity and unnecessary computer jargon or computer-related syntax and semantics issues (Carlson, 1989; Koved & Shneiderman, 1986). Context helps users better comprehend the menu items and make selection.

This selection-in-context could prevent users from the so-called "Escher Effect" (Ramey, 1989) when reading online text. From the paintings of M.C. Escher, viewers often experience a sense of disruption and dislocation (Jaynes, 1989). This sense comes from Escher's breaking the rules that govern the physical relationships between objects and the relationships between the creator and the thing created (Ramey, 1989). Explicit menus may be subject to such flaw because of their telegraphic style of menu items and lack of contextuality. Users of systems with embedded menus with rich contextuality may be less likely to experience such effect during reading. However, embedded menus have their problems too. Koved and Shneiderman (1986) propose three possible disadvantages of embedded menus. First, highlighting of phrases may be disruptive to readers, reducing reading speed and comprehension. Second, novice or inexperienced users may get lost more easily. Third, users may forget the original context in which the material was retrieved. Despite these suspicions, in their experiment of information searching in a database implemented in *Hyperties* describing the Student Union at a major university in the east, they found that embedded menus resulted in significantly better user satisfaction, fewer screens viewed, and more questions answered correctly (Koved & Shneiderman, 1986). The researchers concluded that all things considered, embedded menus seemed to be an attractive alternative for menu design. Their findings were contradictory to Rada's (1991) experiment in which *Hyperties* was compared with *SuperBook*, which has an explicit menu.

While systems that do not provide clearly signaled structure, such as *Hyperties*, may satisfy a general audience's curiosity when browsing through an online museum exhibition information display (Shneiderman, Brethauer, Plaisant, & Potter, 1989), they may not meet the need of users who want to "find and do" (Herrstrom & Massey, 1989). The call for clearly signaled structure has grown stronger and researchers have come to realize that the provision of an appropriate organizational model will help users comprehend information better and facilitate the

location and retrieval of specific information (Herrstrom & Massey, 1989; Jaynes, 1989; Jonassen, 1988; Jonassen & Grabinger, 1990; Rubens, 1989; Simpson & McKnight, 1990). Gluck (1989) points out that issues such as speed, graphical browser, user editing capability, and cost and time of development are "superficial" problems. These problems can be solved with increased computer speed and power. The real "deep" problems with hypertext are disorientation, cognitive overhead, and lack of presentation rhetoric. The first two deep problems have long been identified (Conklin, 1987). The third problem, according to Gluck, concerns the principles and rules of text composition and the ways the intended relationships among ideas are communicated to the learners. The strength of hypertext and important implications hypertext has for online instructional documents are its support for cross-reference and selection-in-context. Cross-referencing may give one faster access to associative information and allow one to see an information node from different perspectives. Selection in context may give one a greater sense of control and confidence in what one chooses to see. With clearly signaled structure and distinction of organizational and referential links, will the cross-referencing feature of hypertext systems still result in the problems of disorientation and cognitive overhead? Or will the intended relationships among ideas be more likely to be communicated? How well do the users interact with such systems? If both organizational and referential links are embedded within text, will this provide users with a more coherent presentation or is it the major source of disorientation? How well can users interact with such systems? Studies which address these issues have not yet been undertaken.

RESEARCH QUESTIONS AND HYPOTHESES

The questions raised in this study are:

1. When search tasks are broken down based on their simplicity, specificity, and clarity of terminating conditions, will network structures facilitate certain type of search task?
2. Will embedded menus facilitate information searching with certain types of search tasks?
3. For search tasks that are complex, will network structures or embedded menus produce answers with greater width or greater depth?[1]
4. Which combination of document structures and menu designs produce better user satisfaction in terms of attitudes towards the document content and the program?
5. Which combination of document structures and menu designs produce greater sense of getting lost and sense of digression?

Method

A document explaining the general computing and computer networking facilities and resources available on the campus of a major mid-western university was implemented into three different versions on Macintosh computers using the *HyperCard* program. The three sets of documents had the same organizational structure and the same user interface. Document Set 1 was purely hierarchical and used explicit menus. Set 2 and Set 3 were built on the same hierarchy as Set 1 but supported referential links additionally. Both Set 2 and Set 3 used embedded menus to signal referential links, but the hierarchical organization was signaled with explicit menus in Set 2 and embedded menus in Set 3. A summary of the differences among the three sets of documents is shown in Table 1.

Table 1
Differences Among the Three Sets of Documents

Document Set	Structure		Menu Design
1	hierarchy		• explicit menus
2	network:	hierarchical organization + referential links	• explicit menus for organizational links • embedded menus for referential links
3	network:	hierarchical organization + referential links	• embedded menus for both organizational links and referential links

[1]The width of an answer is defined as the number of search targets identified. The depth of an answer is defined as the number of details provided for each search target.

Figure 1 shows the main menu for Set 1 and Set 2 and Figure 2 shows the main menu for Set 3. The possible pros and cons of each set of document is given in Appendix A. Set 1 and Set 2 each consisted of 156 small units of information and 256 cards whereas Set 3 contained 147 units and 247 cards. This was a result of the different style of text presentation produced by Set 3's embedded menus which sometimes included information that was in the introductory sections in document Set 1 and Set 2. Information searching was decomposed into five categories based upon three criteria: specificity, complexity/focus, and boundary (see Table 2). The five categories were when the search tasks were (a) simple and fully known, (b) simple but partially known, (c) complex and fully known, (d) complex but partially known, and (e) complex and the condition for terminating the search was unclear.

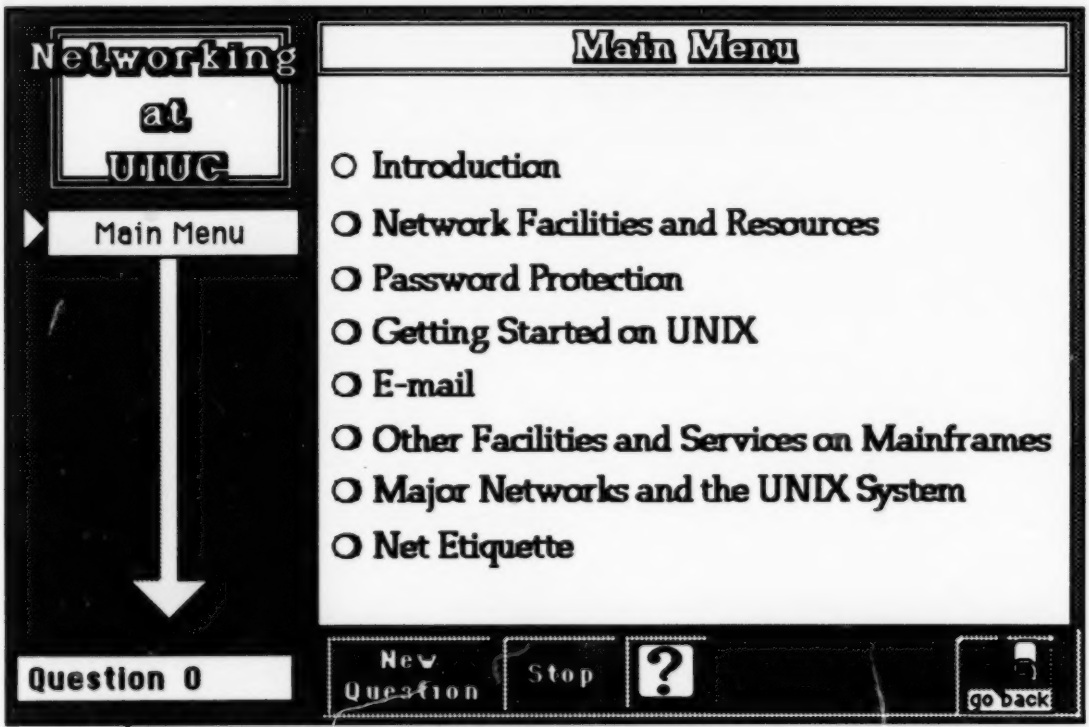

Figure 1. Explicit menus used in Set 1 and Set 2. (Organizational selection items are listed explicitly.)

Hypotheses

As the real value of hypertextual menu design may not be obvious unless the search tasks are complex or unclear, a trend was hypothesized: as search tasks became more complex or unclear, network structured document sets (Sets 2 and 3) would produce better search performance in terms of scores and time. A graphical representation of the hypothesized trend is shown in Figure 3. It was also hypothesized that the network structured document with explicit menus (Set 2) would (a) always result in the best score and fastest search and (b) be better received by users. The network structured document with embedded menus (Set 3) would (a) produce greater sense of getting lost and sense of digression and (b) gradually result in better performance as search tasks become more difficult. Altogether six hypotheses were formulated:

1. For search task 1 (simple and fully known), explicit menus (document sets 1 and 2) will produce higher search score and faster search than the embedded menu (document set 3).
2. For search task 2 (simple but partially known), explicit menu and cross-reference (document set 2) will produce the best search score and the fastest search. Embedded menu (document set 3) will produce the worst search scores and the slowest search.
3. For search tasks 3 and 4 (complex and fully known; complex but partially known), document set 2 will result in the highest search score and the fastest search.
4. For search task 5 (complex and the condition for terminating the search is not clear), document sets with cross-references (document sets 2 and 3) will produce higher score and faster search.
5. Document set 2 will produce the best user satisfaction towards the content and the program.

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6. Subjects using the embedded menu (document set 3) will
   a. feel lost most often, and
   b. report getting distracted to side trails most often.

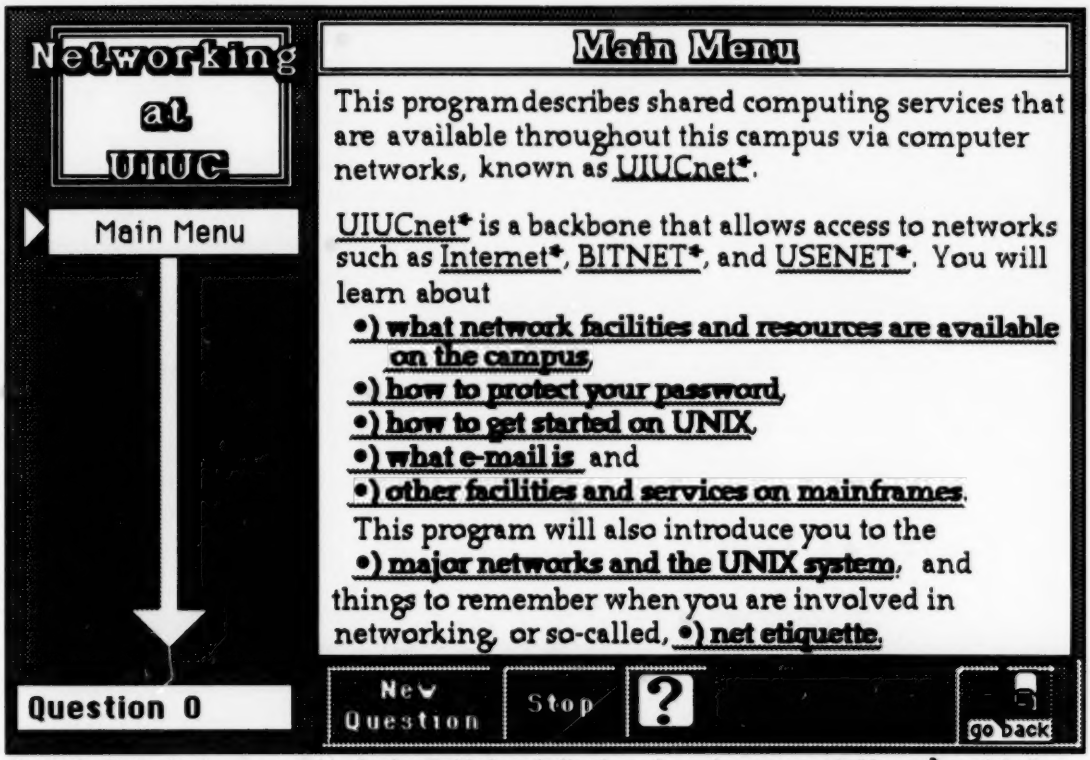
Networking at UIUC
Main Menu
Question 0
Main Menu
This program describes shared computing services that are available throughout this campus via computer networks, known as UIUCnet*.
UIUCnet* is a backbone that allows access to networks such as Internet*, BITNET*, and USENET*. You will learn about
•) what network facilities and resources are available on the campus,
•) how to protect your password,
•) how to get started on UNIX,
•) what e-mail is and
•) other facilities and services on mainframes.
This program will also introduce you to the
•) major networks and the UNIX system, and
things to remember when you are involved in networking, or so-called, •) net etiquette.
New Question
Stop
?
go back

Figure 2. Embedded menus used in Set 3. (Bolded, underlined words or phrases preceded by a •) mark indicate organizational selection items. Underlined words or phrases in plain text followed by an asterisk indicate referential links.)

Table 2
Breakdown of the Five Search Tasks

Complexity	Simple				Complex			
Specificity/ Focus	Fully Known		Partially Known		Fully Known		Partially Known	
Boundary	Known	Unknown (NA)	Known	Unknown (NA)	Known	Unknown (NA)	Known	Unknown
Task #	1		2		3		4	5
Remarks	Since there is only one search target in the search task, the terminating condition is always known.				Since each search target in the task is fully known, the terminating condition is always known.		The search targets are not fully known, but the number of search targets sought is clear.	The search targets are not fully known, and the number of search targets sought is also unclear.

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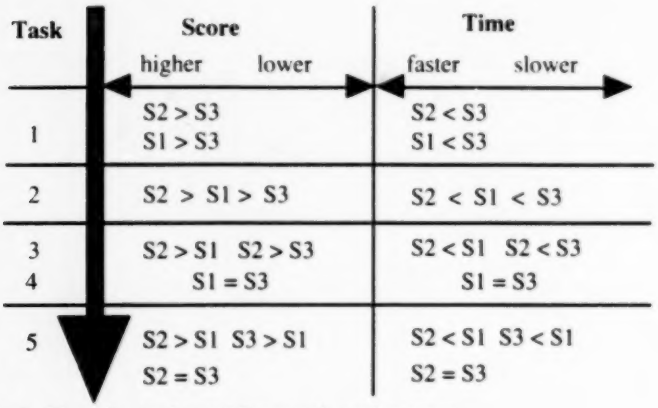

Figure 3. Hypothesized trend for search performance.
Note. The downward pointing arrow indicates the time factor as all subjects proceeded from Task 1 to Task 5.

All three document sets had three areas on each screen: the text area, the organizational hierarchy area, and the button control area (see Figure 4). The text area contained the actual information. It was also the area for menu selection. The organizational hierarchy area was located at the left hand side of each screen. It showed the ancestors of the current information node in the hierarchy. The ancestors were shown in a shadowed square button in bold-faced style, whereas the current node was shown in plain text style and an unshadowed square. A triangle pointer helped remind the subjects where they were in the hierarchy. Subjects could choose to go back to any ancestor by clicking on the shadowed squares. The button control area consisted of five buttons for document Set 1 and six buttons for Set 2 and Set 3. The "New Question" and "Stop" buttons were for the purposes of online data collection. Subjects were asked to click at these buttons to indicate the start and the end of searching for each question. The left-pointing and right-pointing arrows were for sequential reading, if so chosen. The "Help" button would branch the subjects to the help screen in which the organization and ways of navigation of the online documents were explained. Since Set 2 and Set 3 provided referential jumps, both had one additional "go-back" button to support backtracking.

Evaluation Tasks

For each search task and for each search question, several data items were collected during the experiment: (a) the length of time taken to find the answer, (b) the search path, which included each card visited and the time spent on that card, (c) the number of times subjects chose to see the help screen, (d) the number of times subjects utilized the left and right arrows for linear reading , and (e) for Set 2 and Set 3, as referential links were supported, the number of times subjects chose to branch through such links and the number of times they used the go-back button for backtracking. Search questions for each search task were selected by two independent reviewers from a question bank. Only questions that were classified into the same categories by both reviewers were adopted. Task 1 and Task 2 each consisted of 4 questions, whereas Tasks 3, 4, and 5 each had 1 question (see Appendix B). A score for each search task was evaluated by the first author and two other raters. The width and depth of the answers to complex search tasks, Tasks 3 and 4, were also evaluated. As more than one component was involved in these complex search tasks, the width of the answers was defined as the number of components identified and the depth was defined as the details provided for each component.

A subject attitude questionnaire consisting of thirteen items was administered at the end of the experiment (Appendix C). The purpose of the questionnaire was to find out how subjects felt about the content and the program and to assess subjects' "sense of getting lost" and sense of digression during their search process. The questions for assessing the sense of getting lost were based on the two phenomena identified by Foss (1989) and the three sources of feeling lost according to Elm and Woods' (1985) study. Foss believes that users of hypertext systems often suffer the "Embedded Digression Problem" and the "Art Museum Phenomenon." The three sources of getting lost identified by Elm and Woods (1985) are: not knowing where to go next, knowing where to go but not knowing how to get there, and not knowing where they are in the overall structure of the document.

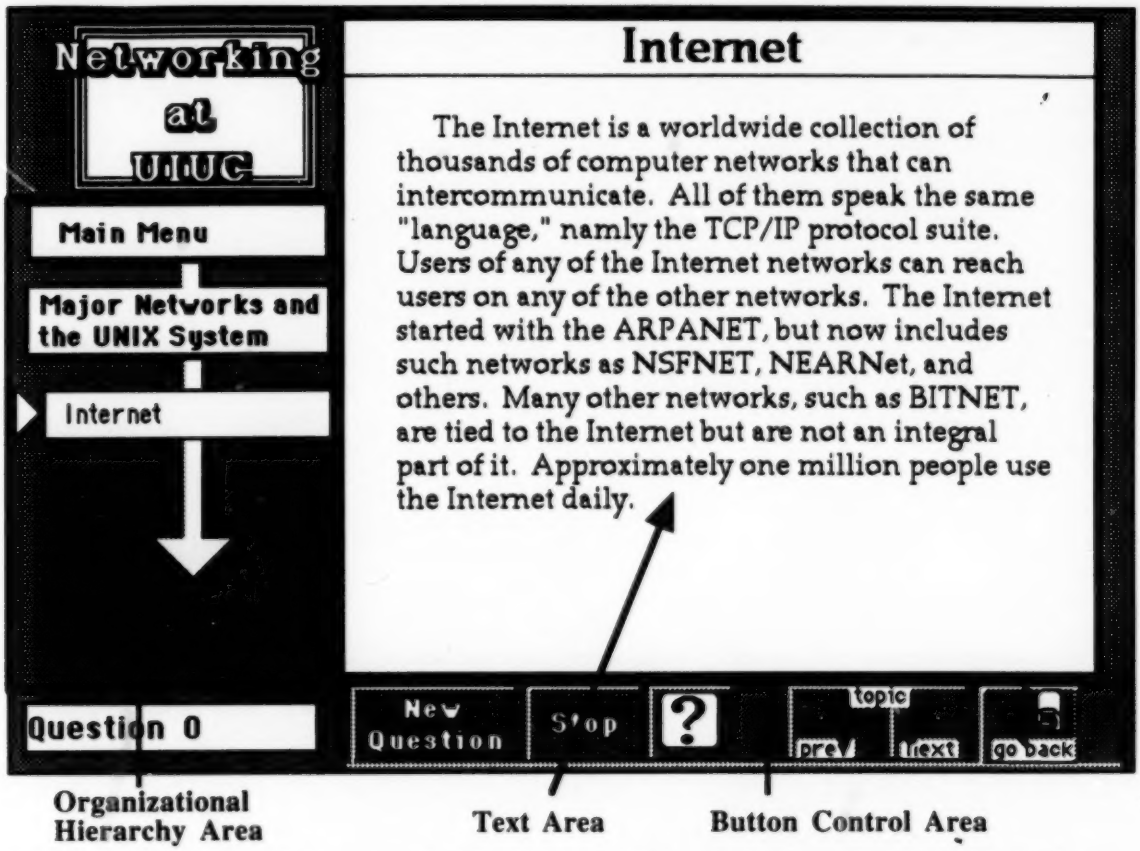
Networking at UIUC
Main Menu
Major Networks and the UNIX System
Internet
Question 0
Internet
The Internet is a worldwide collection of thousands of computer networks that can intercommunicate. All of them speak the same "language," namely the TCP/IP protocol suite. Users of any of the Internet networks can reach users on any of the other networks. The Internet started with the ARPANET, but now includes such networks as NSFNET, NEARNet, and others. Many other networks, such as BITNET, are tied to the Internet but are not an integral part of it. Approximately one million people use the Internet daily.
New Question
Stop
?
topic
prev
next
go back
Organizational Hierarchy Area
Text Area
Button Control Area

Figure 4. Screen layout for the three sets of on-line documents. (The go-back arrow at the bottom right-hand side of the screen is not supported in Set 1 except in cases where subjects branch to the help screen and maps.)

Procedures

The experiment was carried out on Macintosh SE computers in a computer lab. Subjects participated in the experiment two at a time. This was an effort to ensure all subjects clicked at the "New Question" and the "Stop" buttons at the right time. Subjects first spent about 10 minutes viewing an introductory program that explained the procedure of the experiment, the organization of the online document, the function of each button, and the ways to navigate. Then they were shown the actual online document they were going to use and had five minutes to get familiar with navigation and the function of each button. Each subject then carried out all five search tasks, from search task 1 to search task 5. The sequence of search tasks was fixed for all subjects, progressing from the simplest to the most difficult. For the eight questions in Task 1 and Task 2, they had a maximum of ten minutes for each question. For Tasks 3, 4, and 5, they had a maximum of fifteen minutes to search for answers and take notes. After the fifteen minutes, they had all the time they needed to write down the answer, but were advised to write down related concepts and information in a structured way and not to bother writing complete sentences. Finally they filled out the attitude questionnaire (Appendix C).

Data Analysis

While comparisons of time spent on searching and accuracy of search can reveal the efficiency of the three interfaces, "such measures... have less obvious relevance to the process of learning" (McKnight, Richardson, & Dillon, 1990, p. 288). In order to better understand how the different document structures and menu designs affected the way the subjects navigated, search strategies utilized for search tasks 2, 3, and 4 were analyzed based on the sequence of visits to cards. These three tasks were chosen to be analyzed because they took the most time to

complete among the five and significant differences in search scores were found in these tasks. The analysis was based on a scheme characterizing search strategies proposed by Canter, Rivers, and Storrs (1985).

Canter, Rivers, and Storrs draw on three lines of research and propose a detailed characterization of information searching strategies. The first line of research recognizes the parallels between navigation in databases and physical navigation in concrete environments. The second line of research studies social and psychological implications of navigation by providing algebraic specification of the physical structures. The third line of research brings in path algebras for specification and study of interactive systems and database navigation. The five different search strategies they propose are: scanning, browsing, searching, exploring, and wandering, and characterization of these strategies is based on six indices: pathiness, ringiness, loopiness, spikiness, number of unique nodes visited vs. number of nodes visited (NV/NS), and number of unique nodes visited vs. total number of nodes (NV/NT). See Appendix D for a definition of the six indices and the characteristics of the five search strategies.

As a program that will calculate the paths, rings, loops and spikes automatically and correctly from the data has not yet been written, data for five subjects from each treatment group were selected for manual analysis to find out if referential links or different menu designs encourage certain search strategies. Selection was made by listing the subjects in each group ascendantly according to their total scores and the fourth, eighth, twelfth, sixteenth, and twentieth subjects were chosen. The search paths were plotted on a sheet containing the hierarchical structure of the document sets for calculation of pathiness, ringiness, loopiness, and spikiness. They also were loaded into FoxBASE for calculation of NV and NS.

RESULTS

Sixty-nine undergraduate students from the subject pool of the Department of Educational Psychology at a major university in the midwest volunteered to participate in the study as part of their course requirement. They were assigned to three treatment groups according to the sequence they came in for the experiment and thus resulted in a balanced design with 23 subjects in each group. The sample consisted of 17 males (24.64%) and 52 females (75.36%). Their ages ranged from 18 to 23 years old, with 2 freshmen (2.90%), 27 sophomores (39.13%), 23 juniors (33.33%), and 17 seniors (24.64%). The majority of the subjects were Education majors (42 subjects, 60.87%) while Liberal Arts and Sciences majors took up 21.74% (15 subjects), Agriculture majors, 8.69% (6 subjects), Fine and Applied Arts, 4.35 % (3 subjects), and Applied Life Studies, Commerce and Business Administration, and Communication each with 1.45% (1 subject).

Hypotheses Testing

Hypotheses 1-4:

The results of the first four hypotheses testing are shown in Table 3:

Table 3
Results of First Four Hypotheses Testing Concerning Score and Time

Task	Score			Time		
	higer lower	F	*p*	faster slower	F	*p*
1	S2 = S3 = S1	2.27	0.1109	S1 = S2 = S3	0.10	0.9090
2	S2 > S3	4.44	0.0155	S1 = S2 = S3	2.85	0.0649
3	S3 = S2 = S1	1.99	0.1444	S2 = S3 = S1	0.99	0.3785
4	S2 > S1 S3 > S1	4.13	0.0204	S1 = S2 = S3	1.95	0.1505
5	S3 = S1 = S2	2.03	0.1398	S2 = S1 = S3	0.41	0.6658

Hypothesis 5:

Set 2 will produce the best user satisfaction towards the content and the program.

No difference was found for subjects' attitude toward the content ($F=1.45$, $p=0.2413$). However, Set 2 was significantly more popular than document Set 3 and Set 1 ($F=7.18$, $p=0.0015$).

Hypothesis 6:

Subjects using the embedded menu (Set 3) will

a. feel lost most often, and
b. report getting distracted to side trails most often.

Both failed to show any significant difference among the three groups of subjects (sense of getting lost, F=0.15, p=0.8588; sense of digression, F=1.44, p=0.2445).

Further Analysis

As reported earlier, for Task 3 and Task 4, search answers were rated in two categories: width and depth. The previous hypotheses testing was based on the sum of the two categories. Significant differences were found in the width of answers for Task 3 (F=3.97, p=0.0235) and both Set 2 and Set 3 produced higher scores in width than Group 1 (a=0.05) but not in depth (F=0.33, p=0.7236). For Task 4, significant differences were found in the width of answers (F=3.33, p=0.0417) as well as in the depth (F=3.32, p=0.0424). Set 2 produced significantly higher scores in width than Group 1 (a=0.05) while Set 3 produced significantly higher scores in depth than Set 1 (a=0.05). Therefore, when the subjects were not sure about what and how many components they were looking for, network-structured document sets produced better answers in both width and depth, with the explicit menu (Set 2) facilitating the width of search and the embedded menu (Set 3), the depth of search. As for search time, no significant differences were found among the three groups in the time they spent on each of the five search tasks. Even though Set 3 seemed to cost a little more time for most of the tasks, an analysis of variance of the total time spent on all search tasks did not show significant differences (F=2.75, p=0.0711). Based upon the findings, the trend hypothesized in Figure 3 needs to be modified and is shown in Figure 5. Note that in the following discussion, Group 1 refers to subjects using document set 1; Group 2, Set 2; and Group 3, Set 3.

Task	Scores: The Whole Task	Width	Depth
1	S2 = S1 = S3		
2	S2 > S3		
3	S3 = S2 = S1	S2 > S1 S3 > S1	S3 = S2 = S1
4	S2 > S1 S3 > S1	S2 > S1	S3 > S1
5	S3 = S1 = S2		

Figure 5. Modified graph of overall trend for search accuracy.
Note. The downward pointing arrow indicates the time factor as all subjects proceeded from Task 1 to Task 5.

Other Variables

Five other variables were further analyzed: (a) number of times referential links were utilized, (b) number of times go-back links were utilized, (c) number of times forward arrows were used, (d) number of times backward arrows were used, and (e) the total number of visits to cards. For the use of referential links, Group 3 was found to use referential links significantly more often than Group 2 in Task 2 (t=5.98, p=0.0185) and Task 3 (t=7.99, p=0.0070). Overall, Group 3 used the referential links more often than Group 2 (t=7.61, p=0.0084). As for use of go-back links, even though no significant difference was found in individual tasks, overall speaking, Group 3 utilized go-back links significantly more often than Group 2 (F=4.56, p=0.0384). No significant difference was found in either the use of forward or backward arrows, and no significant difference was found in the total number of visits to cards.

Correlation

Correlation among all the previously analyzed variables was examined. Two clear patterns can be seen in these tables:

1. Time spent on searching was positively correlated with the number of visits to cards for all five search tasks.
2. In most cases, the use of forward arrows were positively correlated with the use of backward arrows, and the use of either forward or backward arrows were positively correlated with the number of visits to cards.

Several interesting findings are:

1. Only in Group 1 did attitude towards the program and the sense of getting lost correlate with total score.
2. A positive correlation is found between the use of referential links and the sense of getting lost in Group 2 while no such correlation is found in Group 3.
3. In Group 2 the use of go-back links is positively correlated with the sense of getting lost and negatively correlated with the attitude towards the program, while in Group 3 the use of go-back links did not contribute to greater sense of getting lost or more negative attitude towards the program.

Search Strategies

The strategy utilized by Group 1 can be classified as "scanning" (high NV/NT, high spikiness, medium loopiness), and strategy utilized by Group 2 is "exploring" (high pathiness and high NV/NT).[2] However, no search strategy seems to fit the values found for Group 3 really well. Its ringiness is the highest among the three groups, but its NV/NS is not low enough and its NV/NT does not seem high enough to classify the search strategy as "wandering." With medium loopiness and medium NV/NS, "browsing" seems a better fit than the other four strategies.

DISCUSSION

According to the findings, the interface used by Group 2 produced significantly better search scores in Tasks 2 and 4, i.e., the network-structured document set with explicit menus for organizational links promoted search accuracy for tasks that were only partially known regardless of their complexity. The interface used by Group 3 produced significantly better search scores in Task 4, but significantly worse scores in Task 2. When each search component in a complex search task was known (Task 3), both interfaces used by Group 2 and Group 3 only helped the subjects identify the components in the search task and did not result in more detailed answers for each component. When the search components in a complex search task were not fully known (Task 4), the interface Set 2 employed helped the subjects identify the components while the interface Set 3 employed encouraged greater details for each component. This superiority of network-structured documents would not have been detected if a breakdown of search tasks was not carried out and all search questions had been simple and fully known. Equally important is the finding that embedded menus are good for complex search tasks (Tasks 3 and 4), yet not ideal for tasks that are simple and not fully known. These findings echo the calls in the literature for an increase of the specificity of learning tasks (Dillon, 1990) and a decomposition of search tasks (Wright, 1990) in related research. These findings may also help explain why earlier studies on information searching in hypertext environments with various menu designs have conflicting results.

As discussed earlier, information searchers are often goal-oriented and have little motivation to go beyond what is asked of them. This experiment shows that when what to look for is clear, network-structured documents do help information searchers identify the search targets, but they may not provide more motivation for information searchers to go beyond what is required, especially in this experimental setting where the subjects participated because of a course requirement. Only when what to look for in a complex situation is unclear will the network-structured document with both organizational and referential links signaled by embedded menus (Set 3) promote in-depth searching. The reason why Set 3 encouraged in-depth search in Task 4 is hard to identify. Comparison of the use of referential and go-back links, NV/NT, and NV/NS for Task 4 all failed to show any significant differences with Set 2 or Set 1. There are three possible explanations for this superiority of Set 3 in Task 4. First, while Group 3 did not view more cards or use more referential links, the cards they viewed might have been very different from what Group 1 and Group 2 viewed or they might have viewed the cards in different sequences or different contexts. Second, in general, Group 3 used more referential and go-back links than Group 2. By the time they

[2]Categorization of search strategies for the three groups is based on visual inspection of search patterns used by 15 subjects

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worked on Task 4, they might already have had a different perspective or mental model for the document. This issue of mental models will be further discussed in a later section . Third, subjects in Group 3 who used more go-back links had stronger desire to digress, and Task 4, with its complexity and vagueness, is the best candidate among the five to encourage any such desire.

The result that search scores across groups for Task 5 were not significantly different means that when the size of the document was small enough for exhaustive searching within one sitting and after the subjects had searched the document for other various search tasks, search performance of the three groups for this type of search task was not significantly different. That is, all groups developed a similar "big picture" of the content domain after going through Tasks 1, 2, 3, and 4. After sitting and reading from the screen for more than an hour, neither group was more willing or able to provide greater details. Since in this study the search tasks were sequenced from the simpler to the more complex, this type of sequence as well as the time factor involved could confound the findings. Separate studies of each search task may yield different results. The fact that the three groups of subjects only spent an average of 4.23 (Group 2) to 4.92 (Group 3) minutes for search Task 5 showed that the subjects simply went through the online document in an attempt to "wrap-up" what they had read.

Attitudes

As hypothesized, subjects in Group 2 showed significantly more positive attitudes toward the program they used as compared with Group 3. However, with the other three categories, the three groups did not differ significantly. That is, the structure of the document (hierarchy vs. network) or the design of the menu (explicit vs. embedded) did not seem to affect the subjects' attitudes toward the content, nor did they seem to cause significant difference in the subjects' sense of getting lost or their tendency to digress. This might be because the size of the document was small enough for the subjects to become familiar with the overall structure in two hours, especially when all three document sets were based on the same hierarchy. As the focus of this study is on small or medium sized online documents, it is important to mention that the same result may not be applied to large documents.

Correlation

Findings concerning the use of referential and go-back links are very surprising and intriguing. Since the only difference between Set 1 and Set 2 was the availability of referential and go-back links in Set 2, the discrepancies in search scores should be a result of using these links. However, the use of referential and go-back links was not correlated with search scores yet was positively correlated with the sense of getting lost and negatively correlated with attitudes toward the program for Group 2. For Group 3, the use of either type of link was not correlated with scores or the sense of getting lost, yet the use of go-back links was correlated with the sense of digression.

Similarly perplexing are the findings that even though Group 2 liked their program better, attitude towards the program was not correlated with search accuracy or efficiency. Neither was it correlated with the use of referential links. Actually, those in Group 2 who used more go-back links had a less favorable attitude for the program ($r=-.43$, $p<0.05$). Moreover, the use of referential links was not correlated with search scores for Group 2 and Group 3, and the use of referential links and go-back links was positively correlated with the sense of getting lost for Group 2. As a matter of fact, all these findings ruled out the initial conjectures that if Group 2 and Group 3 had better search performance than Group 1, use of referential links must be the cause. Table 4 lists these initial conjectures and the actual findings regarding attitudes and the use of referential and go-back links.

With the results of the study failing to support the initial conjectures, there must be other less obvious reasons for these discrepancies in search performance and attitude towards the program. For the correlation between search scores and attitude, Group 1 is the only group that showed a positive correlation between search scores and attitude towards the program and a negative correlation between scores and sense of getting lost. These correlations seem intuitively natural, but such relations did not exist for Group 2 or Group 3. This may be an important indication of how referential links change the usual way information searchers use online documents and these changes may trigger mixed feelings in the users. This ambivalence, if it exists, unfortunately, could not be detected by the questionnaire designed for this study.

Two possible explanations for the better search performance by Group 2 and Group 3 are (a) aesthetic appeal and (b) major concepts/terminology hinting. Aesthetically, Set 2 might be more appealing to the eyes than Set 1 as it provided some variation in the style of the text, e.g., underlining. Set 3, even though it also provided variation in the style of the text, might have been too eye-dazzling and complex for its users as both organizational

Table 4
Initial Hypotheses and Actual Findings Concerning the Difference in Attitude and Use of Referential and Go-Back Links

Related Variables	Correlation	
	Initial Conjectures	Actual Findings
• Attitude towards the program • Scores	Would be POSITIVELY correlated for all groups	Were POSITIVELY correlated only in Group 1
• Sense of getting lost • Scores	Would be NEGATIVELY correlated for all groups	Were NEGATIVELY correlated only in Group 1
• Use of referential links • Scores	Would be POSITIVELY correlated for both Group 2 and Group 3	Were NOT correlated in either group
• Use of go-back links • Scores	Would be POSITIVELY correlated for both Group 2 and Group 3	Were correlated in some tasks for Group 2
• Use of referential/go-back links • Attitude towards the program	Both links would be POSITIVELY correlated with attitude towards the program for Group 2 and Group 3	Use of referential links was NOT correlated with attitude towards the program for either group Use of go-back links was NEGATIVELY correlated with attitude towards the program for Group 2
• Use of referential/go-back links • Sense of getting lost	Both links would be POSITIVELY correlated with sense of getting lost for Group 3, not Group 2	Both were POSITIVELY correlated with sense of getting lost for Group 2, not Group 3

and referential links were signaled inside the text. Set 2 was probably the one that resembled paper texts the most in that hierarchical organization was explicitly represented, similar to the hierarchical breakdown of chapters, sections, and paragraphs, and that referential links were signaled within the text, similar to the "see also" convention in paper texts. These might explain why users of Set 2 indicated stronger affinity for this interface. Secondly, referential links in Set 2 and Set 3 might provide visual hints to the subjects by repeatedly bolding or underlining the major concepts and terms in the documents, which is another convention in the paper world and is something readers and information searchers learn from their experience with paper texts. As a result, the subjects might be more willing to try out these "emphasized" phrases.

However, subjects using Set 2 might make less mental effort to keep track of their places and thus have a fuzzier or less appropriate "mental model" of the "information space" as compared with Group 3. A "mental model" is a user's mental image of the structure and internal relationships of the system, and it helps the user to not only understand the system but also draw inferences and make predictions about the system's behavior (Borgman, 1986; Norman, 1983; Manktelow & Jones, 1987; Rupietta, 1990). It consists of both structural and procedural knowledge about the system (Rupietta, 1990). An appropriate mental model can help the user better cope with the system, but an inappropriate one can lead to errors (Young, 1981). Using explicit menus to signal hierarchical structure is a common practice in electronic documents whereas signaling both hierarchical and referential relationships through embedded menus is a newer practice. Therefore subjects in Group 2 might have had lower anxiety (see Appendix A for a list of possible pros and cons of Set 2) and thus made less mental effort to identify where they were in the document and the relation between where they were and where they came from. In short, they developed a fuzzier mental model. Group 3 often used go-back links right after their use of referential links, possibly in an attempt to figure out where they were. Frequent use of referential links by Group 2 without constant effort to keep track of places may have resulted in a sense of disorientation. Subjects in Group 3 seemed to make more efforts to keep track of their places in the information space by using go-back links right after the use of referential links and the data show they went back and forth several times, as indicated by more small loops and rings in Group 3's search paths.

As mentioned earlier , Bolter (1987) argues that going back and forth and reviewing nodes several times may help learners synthesize what they read. It is possible that the unfamiliar interface presented by Set 3 initially

increased Group 3's anxiety and sense of disorientation and therefore their effort to find out the connection among the nodes. Anxiety and disorientation can be a good thing for learning (Mayes, Kibby, & Anderson, 1990). This going-back-and-forth phenomenon might be a strategy Group 3 employed to find out where they were and the relation between the nodes connected through referential links. As the experiment went on, their sense of disorientation might have gradually diminished so that the questionnaire administered at the end did not detect a greater sense of getting lost for this group. Group 2, on the other hand, might not have paid as much attention as Group 3 to the organization and connection of the information nodes, and, therefore, those who used more referential or go-back links possessed a greater sense of having felt lost.

It may be too naive to expect that the differences in search scores between Set 1 and the other two network-structured document sets was caused by the use of referential links and that there was a perfect relationship between the use of referential links and search scores. It is possible that the existence of the referential links made a difference. It is also possible that some use of such links may help but careless use or overuse may have a negative effect on search performance. Knowledge of the organization of the information space may play an important role if information searchers are to take advantage of network branching. What is interesting is that the use of referential and go-back links was positively correlated with the sense of getting lost for Group 2 but not for Group 3. This could mean that either embedded menus did provide a greater sense of context or embedded menus "forced" the subjects to use referential links and go-back links together more often. Note that the use of go-back links was positively correlated with the sense of digression for Group 3, showing that network-structured documents may better encourage pursuit of interest if the menus are embedded.

Actually both Group 2 and Group 3 had trouble using go-back links in the way they were designed to be used--right after the use of referential links. While there is nothing wrong with using the go-back links as a quick-and-dirty way to review cards that were most recently visited, such use might lead to greater sense of getting lost or might be an indicator of the subjects' disorientation in the information space. This is especially obvious with Group 2, whose use of referential and go-back links was correlated with their sense of getting lost. Table 5 shows the correlation between the use of go-back links and the use of referential links. The two did not become significantly positively correlated until Task 3, indicating that perhaps the subjects needed some time to get familiar with such links. Table 6 shows the correlation between the use of go-back links and search scores. Notice that for Group 2, the correlation progressed from very negative to positive to significantly positive, whereas no such trend existed for Group 3. This shows that Group 2 initially had greater difficulties in using go-back links than Group 3, which was possibly the cause of their greater sense of getting lost.

Table 5
Correlation Between Go-Back Links and Referential Links

Group	Task					
	1	2	3	4	5	Overall
2	.08	-.20	.51*	.34	.79**	.19
3	-.02	.12	.48*	.33	.60**	.25

*$p < 0.05$. **$p < 0.01$.

Table 6
Correlation Between Go-Back Links and Search Scores

Group	Task					
	1	2	3	4	5	Overall
2	-.47*	-.28	-.15	.04	.48*	.16
3	-.25	-.07	-.15	-.24	.16	.17

*$p < 0.05$.

Search Strategies

Based upon Canter, Rivers, and Storrs' search strategy classification, users of Set 1 "try to cover a large area without deep depth," users of Set 2 "are seeking the extent and nature of the field," and users of Set 3 "are happy to go wherever the data takes them until their interest is caught." Since document set 1 only supported organizational links, its users were more likely to be "forced" to retrace the in-coming path in order to get out or to branch to another section. This limitation on branching resulted in more spikes in the search path and encouraged the "scanning" strategy. Set 2, on the contrary, encouraged its users to "seek the extent and nature of the field" by providing referential links, which not only offered visual hints of important terms and concepts but also allowed easy access to those sections.

It is interesting that no good fit is found for Group 3, and yet describing them as "happy to go wherever the data took them until their interest was caught" seemed to be an accurate description for those who used more go-back links and had a greater desire to digress ($r=.47$, $p<0.01$). As this desire to digress was not significantly correlated with search scores ($r=.39$), it could mean that sometimes the subjects did tend to follow wherever the links led them and therefore did not have better search scores in some search tasks. It also could mean that Set 3 did present a new combination of document structure and menu design that can not be perfectly described and categorized by this scheme. As a matter of fact, the assumption that high ringiness means wandering or high loopiness means mindlessness might need further investigation. In Group 3, there were many small loops and rings that involved only two, three, or four cards. Many of these happened when the subjects used the referential links and go-back links together back and forth, possibly in an attempt to find out where they were.

Canter, Rivers, and Storrs' scheme does provide a good start and a useful tool for analysis of information searching activity in hypertextual environments (McAleese, 1989), but this analysis identified three problems with this classification scheme. First, in their comparison of search strategies promoted by menu- vs. command-driven interfaces (Canter, Rivers, & Storrs, 1985), the network database only supported uni-directional links. As a result, there would not be the type of small loops or rings as were produced by Group 3 in this experiment. Second, this scheme does not take into consideration the length of loops, paths, rings, and spikes, which may provide important information about what really happens. Third, calculation of the loops, paths, rings, and spikes as defined is a difficult task. Canter, Rivers, and Storrs (1985) also realized this problem:

> [The] indices do present some calculation problems and should not yet be considered a finished tool for characterizing user navigation. Problems of overlap of some of the indices and the need to develop more complex and subtle algorithms remain to be solved. This said, the indices do seem to have present potential as a means of improving the understanding of search strategies, while their continuing development should further improve their power in this respect. (p. 99)

Since their scheme was developed in the mid 80's before hypertext became a popular concept, some modifications may be necessary for this scheme to better describe information searching activity in hypertextual databases.

CONCLUSIONS

While it is impossible to fully understand the potential of hypertext by studying small- or medium-sized electronic documents, providing network structures and referential links for documents of such sizes can still affect search performance and users' attitude. The following conclusions can be drawn from this study. For easier description and understanding, the term EXH (explicit and hierarchical) is used for the kind of document structure and menu design employed in Set 1, EXN (explicit and network) in Set 2, and EMN (embedded and network) in Set 3.

1. <u>This study showed that network-structured documents could improve search accuracy, though not efficiency</u>. In general, EXN worked best. EMN worked best when in-depth search for questions that were complex and only partially known was desired. Neither document structures nor menu designs significantly affected the time spent on searching. The results imply the following:

   a. In an information search task in which the search target is simple yet unclear, EXN can produce better answers than EMN.

   b. In an information search task in which multiple search targets are involved yet each search target is clear, network-structured documents (both EXN and EMN) can produce better answers in width, regardless of menu designs.

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c. In an information search task in which multiple search targets are involved yet not all search targets are clear, network-structured documents can produce better answers in both width and depth, with the explicit menu (EXN) facilitating the width of search and the embedded menu (EMN), the depth of search.

d. In general, for medium-sized information spaces, information searchers will develop a similar "big picture" of the document after searching for various tasks regardless of the document structure (hierarchy or network) or menu design (explicit or embedded).

2. Information searchers favored the EXN design. This was likely caused by the visual appeal of various text styles or the freedom to branch to another topic of interest. It also could be a result of the similarity of such design to paper texts. EMN did not appeal to its users as much. This could be caused by the cognitive burden it put on the users, who needed to be more conscious of what they clicked and where they went as a result of the click.

3. EMN encouraged use of referential links and backtracking after such links without resulting in greater sense of getting lost. Those who used go-back links more often also showed a stronger desire to digress. Therefore, the kind of interface EMN presents can encourage greater mental effort to keep track of places in the information space than EXN can.

4. Users of EXN who used more referential or go-back links showed greater sense of getting lost. The familiar interface and quick cross-referencing capability might cause EXN users to be less aware of their location in the information space as compared to those EMN users.

5. The search strategy utilized by EXH users appears to be "scanning;" EXN, "exploring;" and EMN, closer to "browsing." However, this categorization does not provide a complete picture of what goes on in the searchers' mind.

6. Different combinations of document structures and menu design did not produce significant differences in the ratio of number of interior nodes visited vs. number of leaf nodes visited, the ratio of time spent on viewing interior nodes vs. time spent on viewing leaf nodes, the ratio of unique nodes visited vs. total number of nodes, or the ratio of unique nodes visited vs. number of visits to nodes. What may be different are the nodes visited, the sequence of the visits to nodes, and how the information searchers perceive the association of the information nodes.

7. It takes time for users of EXN and EMN to become familiar with the use of referential links and backtracking after such use. How such use affects users' attitudes is unclear.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should be conducted in the following four areas: (a) a well-defined algorithm and a more detailed scheme for search strategies categorization, (b) qualitative studies on search behavior, (c) modification of this study, and (d) similar studies on large documents.

Future research on search strategies can benefit from a more detailed scheme and analysis of search paths by taking into account the length and size of loops, paths, rings and spikes, which is not considered in Canter, Rivers, and Storrs' scheme. If a certain document structure or menu design promotes searching or exploring, it may not increase the number of paths but rather increase the length of paths. A more detailed definition for these four indices is also critical for future analysis as counting and tallying by hand can be subjective and error-prone. Once a well-defined algorithm is available, a computer program that can automatically calculate the number of occurrences and the size of each occurrence for the four indices can be written to help analyze data on a larger scale.

Even when we know how many loops and rings there are in one's search path, it is still dangerous to assume that loopiness and ringiness necessarily means getting lost or "mindless wandering." In this experiment, Group 3 had more rings and larger loops, but subjects in this group did not report feeling lost and their search performance certainly confirmed this. Canter, Rivers, and Storrs' scheme, while valid for their study with a uni-directional network-structured database, may need some modifications for study of bi-directional or multi-directional network structures like hypertexts. It is also difficult to find out what is in the users' mind unless some qualitative measures are made, such as videotaping during the experiment and interviews afterwards. Future studies should include these types of measures.

Several modifications could be made to improve replications of this study. Future research should design separate studies on each search task, especially with tasks whose terminating condition for search is unclear. Unlike this study which let search experience build on earlier search tasks, separate studies may show different results. Also, data collection may include the number of times go-back links are used right after referential links. This piece of information may provide insight in the actual use of go-back links and help explain why such links cause confusion for some but not for others. Furthermore, the attitude questionnaire should be modified to investigate how the searchers feel about using referential and go-back links and how such use might influence their sense of getting lost and desire to digress. A formative rather than summative evaluation of the searchers' anxiety, sense of

disorientation and sense of digression would provide greater insight in how information searchers feel, what affects their attitudes, and how their attitudes change in the course of time.

Similar studies should be conducted on large documents or sets of documents that cannot be exhaustively searched or browsed within one sitting. The larger the document size, the more easily one can get lost in the information space. Thus, chances are a difference in search performance and search patterns is more likely to be found. However, as the document size increases, categorization of search tasks may change. The word "boundary" may mean the extent to which a search component can be explored rather than the number of search components in a task. Moreover, as the documents become more complex, associative links may get more complicated than just referential. Typed links may need to be provided in order to fully represent this richness of connectivity. But no matter how the search tasks or associative links are categorized, future studies should investigate the searchers' mental model of the information space, the cause of differences in their mental effort to keep track of places, and how a system or interface design can promote greater mental effort and an appropriate mental model without endangering the searchers' confidence in their own control of the search process.

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APPENDIX A

POSSIBLE PROS AND CONS OF EXPLICIT AND EMBEDDED MENUS

Set 1. Explicit Menu WITHOUT Cross-References

Advantages	Disadvantages
• Structural organization is clearly signaled. • Searching for specific, well defined facts may be easier. • Learners are familiar with such menu design. Therefore, users may have low anxiety in using the program.	• Names for menu items may be arbitrary and therefore less well understood by users. • Searching for less well defined purposes may be difficult. • Learners may not have much chance to see the associative relationships among nodes. • Accessing information in other branches of the hierarchy will be difficult.

Set 2. Explicit Menu WITH Cross-References

Advantages	Disadvantages
• Structural organization is clearly signaled. • Searching for specific, well-defined facts may be easier than embedded menu (Set 3). • Searching for less well-defined questions may be easier than explicit menus without cross-referencing capability (Set 1). • Quick access to associative information nodes is made easy. • Learners may better see the associative relationships among information nodes. • Learners may have lower anxiety in using such programs, compared with those using embedded menu. • Learners may have the lowest anxiety in learning the content.	• Names for menu items may be arbitrary and therefore less well understood by users. • Searching for less well defined purposes may be difficult. • Learners can be more easily distracted by side trails than those using strictly hierarchical documentation and forget about the original purpose of searching or reading. • It takes time for learners to get used to using embedded links.

Set 3. Embedded Menu for BOTH Structural Organization and Cross-References

Advantages	Disadvantages
• Quick access to associative information nodes is made easy. • Learners may better see the associative relationships among information nodes. • More information is provided from which learners can judge whether to follow a certain branch or side trail or not.	• Learners may not be familiar with such menu design. • Learners have to be able to distinguish between organizational and referential links in order to use such systems comfortably. • It may take longer time for learners to learn to use such menus as compared to explicit menus. • Learners may be easily distracted by side trails and forget about the original purpose of searching or reading. • Learners may not be able to form a coherent organization for what they have seen.

APPENDIX B

SEARCH QUESTIONS

Task 1. Simple and Fully Known

1. What command should I use on UNIX to change my password?
2. What UNIX command can I use to find out the e-mail address of my friends on this campus?
3. When does the computer lab in Illini Union close on Friday night?
4. What session name should I enter when using Telnet to connect to the Illinet Online Plus (IO Plus), the new online library catalog system?

Task 2. Simple but Partially Known

1. Is there help available on UNIX that explains how to carry out an online conversation with another person on uxa? How can I access such information?
2. What command should I use to see what files I have and when they were last modified in my uxa account?
3. I was playing around on uxa and accidentally got into a program. I couldn't get out of the program since there is no instruction on the screen telling me how to quit, so I just turned the terminal off. Is that OK? What should I do in case similar things happen again?
4. My friend gave me a file GBuster.cpt that she got from the mainframe. She said it is a free program for Macintosh computers. But how come when I tried to open it, it said something like "The file cannot be opened. The application is either busy or missing?"

Task 3. Complex and Fully Known

1. I've heard about (1) **Internet**, (2) **BITNET**, (3) **Telnet**, (4) **UNIX** and (5) **uxa**. But what are they and how are they related?

Task 4. Complex but Partially Known

1. I have an IBM compatible computer at home. What else do I need in order to get on to the University's online library catalog, searching, checking out, and renewing books from home? Do I need to have a mainframe account? Does it make any difference if I don't?

Task 5. Complex and Condition for Terminating Search is Unclear

1. I was told that as a U of I student I can get a free UNIX account. What can I do with this UNIX account?

APPENDIX C

ATTITUDE QUESTIONNAIRE

Scales		Questions
1.	Attitudes Towards the Content	2, 6, 7
2.	Attitudes Towards the Program	1, 3, 8, 12, 13
3.	Sense of Getting Lost	4, 5, 9, 10
4.	Desire to Digress	11

The following statements are intended to find out what you felt about the online document that you just read. Please note that throughout the questionnaire "the program" or "this program" is used to indicate the online document. For each statement, please circle the number that corresponds to the degree to which you agree or disagree.

		Strongly Disagree <------> Strongly Agree						
1.	I felt that I could find answers to the questions quite easily.	1	2	3	4	5	6	7
2.	I found the content of this program to be interesting.	1	2	3	4	5	6	7
3.	The program was easy to use.	1	2	3	4	5	6	7
4.	I often had trouble figuring out where I was in the program.	1	2	3	4	5	6	7
5.	I often had trouble finding a section I know was there somewhere.	1	2	3	4	5	6	7
6.	I feel more comfortable about the subject of networking facilities on this campus than I did before.	1	2	3	4	5	6	7
7.	I would recommend that my friends get to know more about networking facilities on this campus.	1	2	3	4	5	6	7
8.	I would recommend that my friends use this program to learn about networking facilities on this campus.	1	2	3	4	5	6	7
9.	I often felt that I didn't know where to go next when using the program.	1	2	3	4	5	6	7
10.	Sometimes I got distracted and forgot why I came to where I was.	1	2	3	4	5	6	7
11.	Sometimes I felt like going to sections that I was interested in rather than pursuing the answers to the questions.	1	2	3	4	5	6	7
12.	I liked reading when using the program.	1	2	3	4	5	6	7
13.	I found it easy to summarize what I had read after reading the text in the program.	1	2	3	4	5	6	7

APPENDIX D

DEFINITIONS OF THE SIX INDICES USED IN CANTER, RIVERS, & STORRS' SCHEME AND CHARACTERIZATION OF FIVE DIFFERENT SEARCH STRATEGIES

Index	Definition	Diagram
Pathiness	A path is a route through the data which does not cross any node twice.	
Ringiness	A ring is a route which returns to the node at which it starts, such a ring may include other rings.	
Loopiness	A loop is a ring which contains no other structures and typically stands alone.	
Spikiness	A spike is a route which on the return journey retraces exactly the path taken on the outward journey.	
NV/NT	The ratio of the number of different nodes visited (NV) to the total number of nodes available in the system (NT). This ratio is always in the range of 0 to 1.	
NV/NS	The ratio of the number of different nodes visited (NV) to the total number of visits to nodes (NS). This ratio is always in the range of 0 to 1.	

Strategy	Characteristics	Description
Scanning	High NV/NT High spikiness Medium loopiness	Users try to cover a large area without deep depth.
Browsing	Medium loopiness Medium ringiness Medium NV/NS	Users are happy to go wherever the data takes them until their interest is caught.
Searching	High spikiness Medium loopiness Low NV/NS	Users are motivated to find a particular target and therefore create many spikes.
Exploring	High pathiness High NV/NT	Users are seeking the extent and nature of the field.
Wandering	High ringiness Low NV/NS Medium NV/NT	Users amble along and inevitably revisit nodes in an unstructured journey.